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AVAILABLE IN "72" - VOYAGEUR FLAT BED CARGO CARRIERS

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SUMMARY Bell Aerospace Canada and the Department of Industry, Trade, and Commerce are currently proceeding in a joint venture to establish a commercially viable ACV product compatible with operational needs in the Northern Canadian environment. Numerous studies and Arctic trials have already shown the technical potential for the ACV. However, no suitably designed vehicle currently exists which can offer sufficient economic advantages over other means of cargo transport. To meet this need, the Voyageur was conceived.

Voyageur is a flatbed craft which allows rapid handling of a wide variety of different cargoes, and also permits the addition of superstructures to meet particular customer needs. This basic vehicle is constructed in modular form, such that it can be shipped via C-130 cargo aircraft and subsequently be assembled on site. Individual hull structural modules are designed around the use of welded 6000 Series aluminum extrusions. These extrusions are in the form of hollow core planking and joint sections. On final assembly, bolted splice plates are used to structurally join the modules.

The skirt system will be an adaptation of the successful SR.N6 with 50% fingers and supplied by the British Hovercraft Corporation. Neoprene covered nylon fabric will be used.

The two prototype craft will differ primarily in their engine and crew station installations. The first being powered by two G.E. LM-100 engines and the second by two U.A.C.L. ST6T-75 Twin-Pac engines. Each engine installation will drive, through appropriate gearing, a Bell SK-5 centrifugal lift fan and Hamilton Standard propeller. The ST6T-75 installations will provide a measure of four engine reliability, together with increased thrust. The first vehicle will be ready for manufacturers trials by the end of this year. These trials will be conducted at the Bell Aerospace Canada facility at Grand Bend, Ontario, which is on the eastern shore of Lake Huron. The second vehicle will roll-out early in March of next year and undergo a similar trials program.

INTRODUCTION The selected designation, Voyageur, is indicative of the underlying design philosophy applied to the vehicle. More than 200 years ago, a brisk trade was carried on between Montreal and the distant western shores of Lake Superior, using rugged 36 foot, 5 ton capacity, Voyageur canoes. A round trip was completed once per year and involved the negotiation of open lakes, fast shallow rivers, and overland portages. The success of this venture was dependent on the exploitation of a means of transportation well suited to the environment.

In the case of ACV's numerous studies and Arctic trials have shown the potential for such vehicles. However, a suitably designed vehicle, which can offer significant economic advantages over other means of Arctic cargo transport, is needed to exploit the promise demonstrated by earlier craft.

Considerable market research preceeded establishment of the present configuration of the craft. Foremost among the various considerations were:-

1) a fully amphibious, general purpose (flatbed) cargo vehicle.
2) a modular vehicle transportable in sections by C-130 Hercules aircraft, trucks, or railroad cars.
3) a payload capability comparable to that of the C-130. i.e. 15-25 tons.
4) a vehicle utilizing existing "state of the art" components where practical.
5) low cost with adequate performance for commercial applications.

The craft configuration which evolved from these considerations is shown in Fig. 1. The general purpose utility of the design has been maximized by providing a flat forward deck of approx. 1280 sq. ft. (32 ft. x 40 ft.) Cargo lengths up to 60 ft., such as steel pipes, can be accommodated by use of the additional space available under the elevated center located control cab. Payloads up to 25 tons are within the capability of the design for overland distances in the order of 150 statute miles. With reduced payload, the fuel capacity is sufficient to extend the range to over 500 statute miles. Use of the off-the-shelf components has been applied by the utilization of proven Bell SK-5/BHC SR.N6 components relating to transmissions, lift fans and skirt systems. Engine options incorporated in the prototype craft are both well proven designs, the first being the General Electric LM-100 and the second the United Aircraft Canada Limited ST6T-75. These are "marinized" versions of the T-58 and PT6T Twin-Pac aircraft engines, respectively.

The new development associated with the vehicle design, and also the one directed toward a significant cost reduction, is the hull structure itself. Conceptually, numerous Bell in-house studies have shown that hollow-core extruded panel sections, offer many advantages for primary structures. Panels of this type are currently used in military and commercial ship superstructures. However, their application to a complete structural unit has not previously been put to practice. Use of this material with extruded corners for joining of paneling and bulkheads makes a structural box of great stiffness, which is inherently stable under high shear and compression loadings. The requirements of Voyageur for a low cost, rugged structure to withstand expected operational useage, and the capabilities of hollow-core panels complement each other. The hull structure design is based on flat surfaces and thus, eliminates formed parts and greatly reduces tooling costs. Additionally, wherever possible, welding is used to join the extrusions for further cost savings. The major technical challenges associated with this design approach are maintaining material strength properties in the "as welded" condition, and avoiding unacceptable distortions in the large all-welded structures.

VEHICLE STRUCTURE The basic craft hard structure is designed to be broken down and transported in twelve sections as shown in Fig. 2. These consist of three forward flotation boxes, two forward side decks, two power modules, an aft center flotation box, a cabin support pedestal, and the control cabin.

The three forward flotation boxes are essentially the same and nominally measure 40 ft. long, 8 ft. wide, and 37 1/2 inches deep. The major difference in these boxes is that the port and starboard boxes each contain a fuel tank, comprised of three interconnected cells, and a landing pad support structure.

The aft center flotation box is constructed similarily to the forward boxes, being shorter in length with scallops formed in each side to prevent airflow blockage around the perimeter of the lift fans which are contained in the power modules situated on either side of the center box. This module, together with the three forward boxes, forms the structural backbone of the vehicle. Loads from the side decks and the power modules are transmitted into this primary structure.

With the exception of those portions of the SK-5/SR.N5 used in the power modules, all other structural sections are fabricated from the 6000 series aluminum extrusions and plate. Extrusions are in the form of hollow core planking, joint sections, and square section tubing. Wherever possible, welding is used to join the extruded sections. When riveting is necessary, as is the case with the power modules which consist of modified SK-5/SR.N5 structures fabricated from L63 and L73 aluminum, a sealant is used between the surfaces, and blind rivets are installed wetted with sealant.

Fig. 3 shows sections of the hollow core planking used to fabricate the hull. Dimensionally, three different sections of hollow core planking are used in the craft structure. The heaviest is used for the upper decking on the forward flotation boxes where the maximum longitudinal bending moment occurs, in addition to a design criteria allowing 1000#/ft.^{2} cargo limit load. The next heaviest section is used for the bottom planking on all forward and the aft center flotation boxes. This planking is also used on the deck of the forward side hulls and the aft center box, where the deck limit load is also 1000 #/ft.^{2}. The lightest plank is used for the vertical bulkheads within the flotation boxes and for the decking on the aft side hulls of the craft where the deck limit load is 250 #/ft.^{2}. Transverse bulkhead spacing is basically 33 inches on center for the forward flotation boxes. The transverse structure in the aft sections is on 29 inch centers to be compatible with the SK-5/SR.N5 structure used in the power modules. Within the flotation boxes, selected bulkheads have been made watertight to provide reserve buoyancy in the event of damage. Additionally, a buoyancy compartment has been provided at the most aft end of the outboard side hulls. These side hull compartments minimize submergence of the lift fan, which could occur when beaching the bow of the craft with the stern still waterborne. The end result of this compartmentization is 24 individual buoyancy sections, with provisions for draining from below, and pumping out collected water with a portable external bilge pump from above deck. The total buoyancy of the craft is more than three times the normal design gross weight.

Four landing pads are provided to support the vehicle on hard surfaces. A pad is located on each outboard forward flotation box and on each power module. The pads are positioned sufficiently inboard to preclude damage to the side skirts on a landing with sideslip. The pads are 10 inches in height and each has a ground surface area of approx. 530 sq. in., giving an average footprint pressure of 37 lbs. per sq. inch at a gross weight of 78,000 lbs. The pads are designed as replaceable foam filled thin metal containers. The foam material will crush at 85 lbs. per sq. inche to prevent damage to the primary hull structure. The ground contact surface is abrasion-resistant, 1 inch thick oak wood. The metal container is 6061 aluminum with Nopcofoam H104 (density of 3.2 to 3.5 lbs./cu. ft.) as the foam material.

The individual hull modules are joined with horizontal and vertical splice plates, using 5/16" diameter steel bolts. A typical joint between the forward flotation boxes is shown in Fig. 4. To the top of each vertical splice plate between the forward boxes or a forward box and a side hull, a cargo tie-down fitting is attached. This arrangement results in a pattern of four rows spaced approx. 104 inches apart with tie-down fittings located every 33 inches along the row. Each of these steel tie-down fittings consists of a ring, chain links, and a shackle assembly, and has an ultimate load capacity of 15,000 lbs. These fittings are used in combinations for hoisting the craft with appropriate slings.

All splice plates are made of aluminum, except for a small section around each tie-down ring and at the bow towing eyes where steel is used. The bow towing eyes are each designed for an ultimate load of 10,000 lbs. and are located at the forward end of each row of upper longitudinal splice plates. This provides four forward towing eyes. Two stern towing eyes are provided at the corners of the aft center flotation box which are each designed for an ultimate load of 6,000 lbs.

The fabrication of the hull structure, with the exception of the power modules, has been sub-contracted to Fleet Mfg. Ltd. of Fort Erie, Ontario. The development of the welding techniques and tool designs to join the hollow core planks into panels, and subsequently weld the complete box assemblies, represented a major technical challenge. Automated welding equipment has been employed to minimize the total heat input required for satisfactory weldments. Reduction of the heat input has the two-fold advantage of maintaining good strength properties in the "as welded" condition and of minimizing distortion. Minimum ultimate tensile strengths of 24000 PSI after welding have been obtained in the 6105-T6 and 6061-T6 alloys used. Fig. 5 shows an automatic pulsed arc MIG welding fixture with dual heads. This apparatus is used to butt weld simultaneously both sides of the hollow core planks into panel sections in lengths up to 40 ft. Fig. 6 shows a completed panel 8 ft. wide by 32 ft. long of the lightest weight (.055 wall) planking, which was subsequently cut for use as transverse bulkheads.

At this stage in the program, the first forward flotation box has been completed and removed from the assembly fixture. Overall welding distortions are within acceptable limits and the all-welded hollow core structural design approach appears well founded.

SKIRT SYSTEM The skirt system which is being developed in association with the British Hovercraft Corp. is shown in Fig. 7. Most of the configuration is a modification of the well proven SR.N6 design, using 50% peripheral fingers. The longitudinal keel, rear trunks, transverse stability trunks, and the peripheral skirts along the sides of the craft are all extensions of the SR.N6 designs. However, the skirts around the bow section make a transition to a higher outer attachment hinge line across the bow, similar to that employed on the BH-7 design. This design approach at the bow will improve the over-water plough-in resistance of the craft. The skirt system is being fabricated of neoprene coated single ply nylon material. Material weights varying from 40 to 85 ounces per sq. yard are utilized in different portions of the skirt system.

The air flow to the side and bow skirts is supplied through the duct formed by the side hulls. The transverse stability trunks are also supplied from this side hull airflow via a duct built into the outboard forward flotation boxes immediately forward of the fuel tank. The port and starboard rear trunks are supplied by rearward airflow from their respective fans. The longitudinal keel is fed by ducts leading from each fan toward the center of the aft center flotation box and then downward into the keel bag.

FUEL SYSTEM The fuel system being built into the two prototype craft has a total capacity of 1980 Imperial gallons. A tank is provided in each of the forward outboard flotation boxes by utilizing the space between transverse bulkheads to form individual fuel cells. Fig. 8 shows the port tank installation. Three adjacent bays are used, with appropriate interconnections to form each tank. Flexible rubber cells are installed to contain the fuel in each bay. The fuel cells will be supplied by Uniroyal and are constructed of a three ply nylon material which is impregnated with Buna-N rubber to a total thickness of .024 inches. The bottom of each fuel bay is built up with foam and covered with fiberglas to provide a 2 degree slope toward the outboard end of the compartment, and to form a sump in the center cell. The outlet and filling connections, as well as the quantity transmitter, are all installed into the center fuel cell. Each fuel cell contains two laced-in rubber baffles to minimize sloshing due to rolling motion of the vehicle. A 10" x 16" access door is provided into each fuel bay at the outboard end. These doors permit installation and interconnection of the individual cells and are sealed with "O" ring gaskets for final closure. These openings are easily accessible, since they are under the side decks. Normally, the port and starboard tanks are not interconnected and each supplies its respective engine. However, fluid lines and an electrically operated valve are incorporated to permit operation on one tank. The fuel booster pumps selected are 28 volt vane type units and have the capacity to supply both engines at normal power. In the event of damage to one tank, or the desire on the part of the operator for lateral trim reasons, fuel can be drawn from either tank by opening the crossover valve and turning off one booster pump. Should a booster pump fail, a low cracking pressure check valve has been provided in parallel with the pump to enable normal engine operation to continue for a limited period on the engine driven fuel pump only.

The full fuel capacity designed into the vehicle can provide a range of approx. 500 miles. Applications requiring a lesser capability could be fitted with either one or two cell tanks for reasons of economy and reduced residual fuel weight.

PROPULSION SYSTEMS Propulsion for the two prototype craft differ in the engines used. The first vehicle will use General Electric LM-100 engines. These are the same engines used in the Bell SK-5 vehicles, which have been operated extensively by the U.S. Army, Navy, and Coast Guard. The LM-100 has an output shaft speed of 21000 RPM and requires two reduction gear boxes to drive the propeller and lift fan. The first gearbox reduces the shaft speed to approx. 6300 RPM and the second unit further reduces the speed to operate the propeller at 2000 RPM and the lift fan at 952 RPM through a right angle drive.

The second vehicle will be powered with UACL ST6T-75 Twin-Pac engines. These engines have two separate gas turbine sections which drive into a combining gearbox at a 100% rated speed of 33000 RPM. The output speed from the combining gearbox is 6600 RPM at maximum rating. The use of the Twin-Pac therefore eliminates the need for the first gearbox used in the LM-100 installation and provides twin engine reliability for each integrated lift fan and propeller. The Twin-Pac engines are more powerful and can provide approx. 600 additional horsepower. This reserve capability is particularily desirable for overcoming shallow water hump drag conditions in waterborne applications.

Both craft will utilize standard SK-5 centrifugal lift fans and Hamilton Standard Model 43D50 hydraulic operated, variable pitch propellers. The second gearbox used in the Twin-Pac installation will be an uprated "Americanized" version of the original SR.N5 design, which has been developed by the SPECO Division of the Kelsey-Hayes Corporation.

Both engine installations are supplied with air from the cushion plenum. The air supplied to the compressor inlet is obtained through two intake ducts for each engine. These ducts are located on the inboard and outboard side of each lift fan. The velocity vector of the airflow is such as to separate dense particles from the air entering the duct. Duct airflow is subsequently passed through a knit-mesh filter before entering the engine. This type of inlet filtering system was evaluated in sand conditions found in the Libyan desert and found to have considerable merit. It has been selected for Voyageur as a possible solution to snow and ice ingestion that could be encountered in an arctic environment.

CONTROL STATION The control station for the vehicle is located in an elevated position between the power modules. This position was selected as the best compromise to satisfy numerous potential applications. The cab is elevated sufficiently to provide 6'4" of headroom for personnel or cargo and provides the operator with good visibility over the cargo deck and around the craft. The major design difficulty associated with this location is the relatively high external noise levels which must be considered in the cab design.

The control station is housed in a modified four door truck cab. The basic unit, shown in Fig. 9, has a width of 94 inches and a length of 104 inches. The operators position is on the forward starboard side, and the relief driver or radar operator is at the forward port position. Both forward seats are Bostrom Viking "T" Bar designs with arm rests. A control console is located between the two forward seats and contains the control levers for the engines. Propeller pitch controls are located on the starboard side of the operators seat, such that they can be positioned with the right hand while power can be controlled with the left hand. A conventional foot operated control bar is provided for rudder actuation by the operator. Controlex cables are used to transmit mechanical movements from the control station to the engines and rudders. This design was selected because of its inherent low friction and sealing provisions which are essential in the low temperature arctic environment. All other controls to the craft are electrically actuated from the control station.

A full width bench seat is located across the back of the cab, with access provided by the two rear doors. Seat belts are installed for four passengers. Beneath the bench seat, the necessary equipment for the air operated windshield wipers and washing system are installed. Space is also available for other items. The basic cab structure is being supplied by Freightliner of Canada Limited, Burnaby, B.C. The structure utilizes 5052-H32 and 6061-T6 aluminum alloys. The windows are tinted and made of tempered glass to Government standards and are located to provide maximum visibility through 360°. Windshield wipers are installed on the two forward windows and on the center aft window. Two inches of incombustible insulation are installed on all exterior walls and roof of the cab with a black Naugahyde interior finish. Wood battens are used between the aluminum structure and interior attachments to prevent condensation and heat loss in the arctic. Similar insulation is used under the cab floor. The installation of this thermal insulation will also attenuate engine noise levels in the cab. Cabin heating and window defrosting will be accomplished with a heater, burning vehicle fuel, mounted at the forward end and beneath the port walkway to the control cab. External ducting will direct the heated air under the cab and up into the rear of the center located control console. From this point the air will be distributed by internal ducting for heating and defrosting. Consideration has been given to the installation of electrically heated windows, if found necessary.

Additional features provided in the cab design are structural provisions for roof mounted radar and air conditioning installations, and space provisions in the center console for electronic communication and navigation equipment.

MODEL TESTING Current performance estimates are based on model testing of a vehicle considerably larger than the Voyageur, namely a military Assault Landing Craft grossing over 300,000 lbs. which is now being developed under U.S. Navy contract by the Bell Aerospace Company in New Orleans. The present thrust/drag versus speed estimates are shown on Fig. 10. As originally conceived, the Voyageur program permitted extensive evaluation of the first two prototypes prior to sales. The potential market is developing at a faster rate than originally anticipated, and thus testing of a model reflecting Voyageur as accurately as possible was deemed appropriate to verify earlier estimates and to determine dynamic handling characteristics relating to controlability. A model, shown in Fig. 11, has therefore been built and is presently in test at the Bell Aerospace Company, ACV Laboratory in Buffalo, New York.

The 1/7.5 Scale was selected to permit the use of available centrifugal fan units previously proven in Bell SK-5 model testing. The Voyageur model utilizes four electric motors to enable independent power to each lift fan and propeller. Thus, variable distribution of power between the fans and propellers is possible to simulate actual vehicle operation. The model test program will provide data relating to the influence of gross weight and center of gravity location on drag, and dynamic handling characteristics. Directional stability tests will also be conducted as they relate to aerodynamically different payloads on the basic flat-bed cargo vehicle. Model testing is scheduled for completion early in October. Data obtained during the program may well influence decisions to incorporate additional control features in the prototype craft, particularily in reference to specific operational needs. In anticipation of model test results, preliminary designs are now in progress on longitudinal ballast and bow puff-port installations, which may be required for certain vehicle applications.

OVERALL PROGRAM STATUS The program is proceeding according to plan. Major vendor items, such as flotation boxes from Fleet Manufacturing, control cabs from Freightliner, skirts from British Hovercraft, and Twin-Pac engines from U.A.C.L. are being delivered on a schedule to permit rollout of the first craft in December 1971, and of the second craft in March 1972. Each of these craft will undergo similar development trials. Initial tests will be conducted at the Bell Aerospace Canada facility located at the airport near Grand Bend, Ontario. After completion of overland testing, each craft will be moved a distance of approx. three miles for overwater testing on Lake Huron. The mid-winter climate on the eastern shores of Lake Huron is expected to provide useful pre-arctic experience in evaluation of the first craft.

From the performance standpoint, some sacrifice in the original goal has been made by permitting limited weight growth in the interst of craft flexibility and ruggedness. However, we are confident that the Voyageur will offer economically competitive performance in association with exceptional adaptability for many applications.

DIMENSIONS

Length	64.8 ft.
Width	36.7 ft.
Height (on-cushion)	22.0 ft.
Height (off-cushion)	18.8 ft.
Skirt Height	4.0 ft.

WEIGHTS

Weight empty	33,600 lb.
Design Weight	78,000 lb.
Maximum Gross weight	88,000 lb.
Fuel (Maximum tankage)	1,980 Imp. Gal.
Crew	two
Additional Seats	four

ROTATING MACHINERY

Power plant - two Twin-Pac ST.6 units 1300 SHP (continuous) each (United Aircraft of Canada/Pratt & Whitney) or two General Electric LM.100/T.58.

Propeller - 2 three-blade, variable pitch 9 ft. diameter (Hamilton Standard)

Lift Fan - two 7 ft. diameter centrifugal

PERFORMANCE

Maximum over water speed (calm at design gross weight	47 m.p.h.

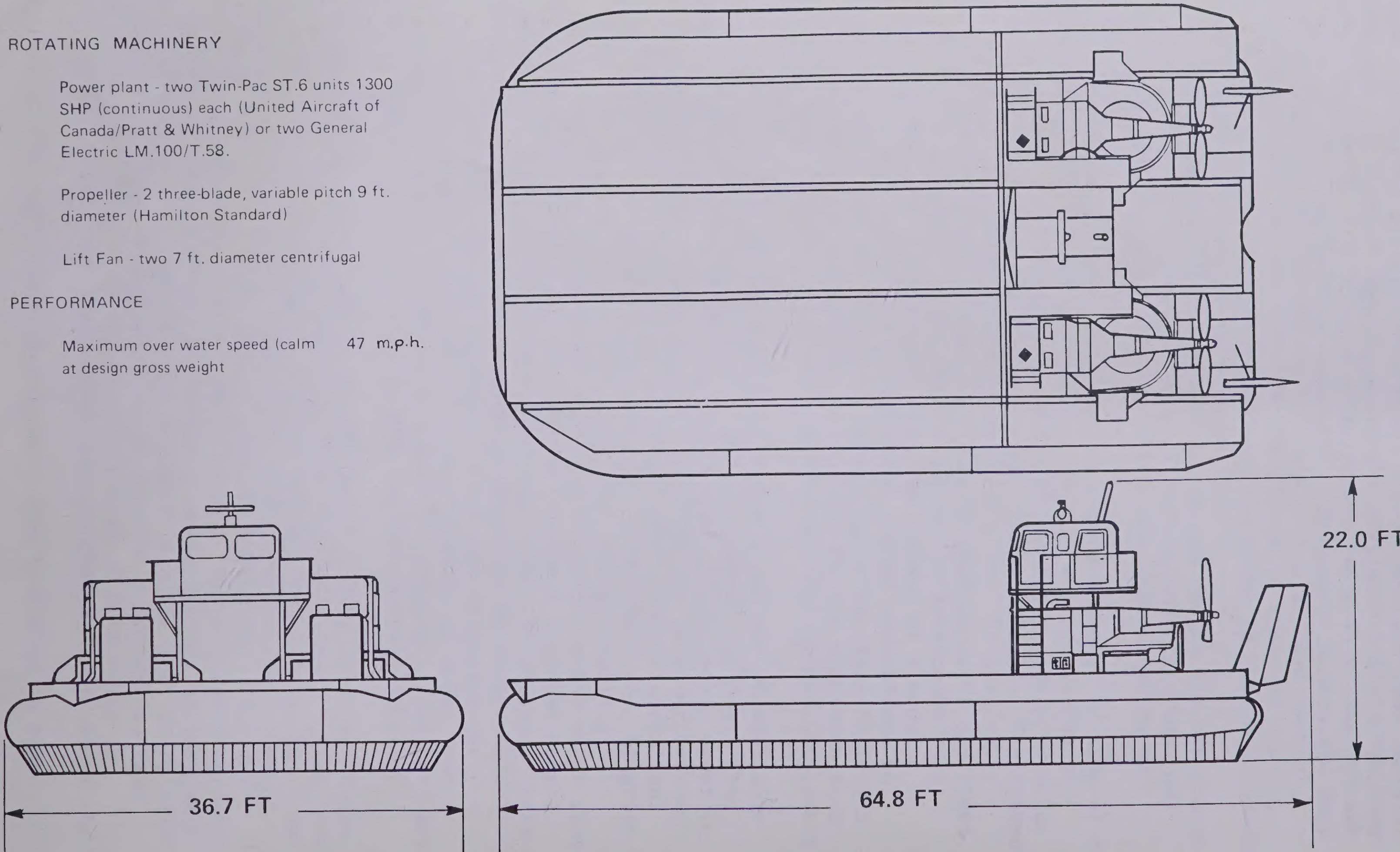

Figure 1. General Arrangement - Voyageur

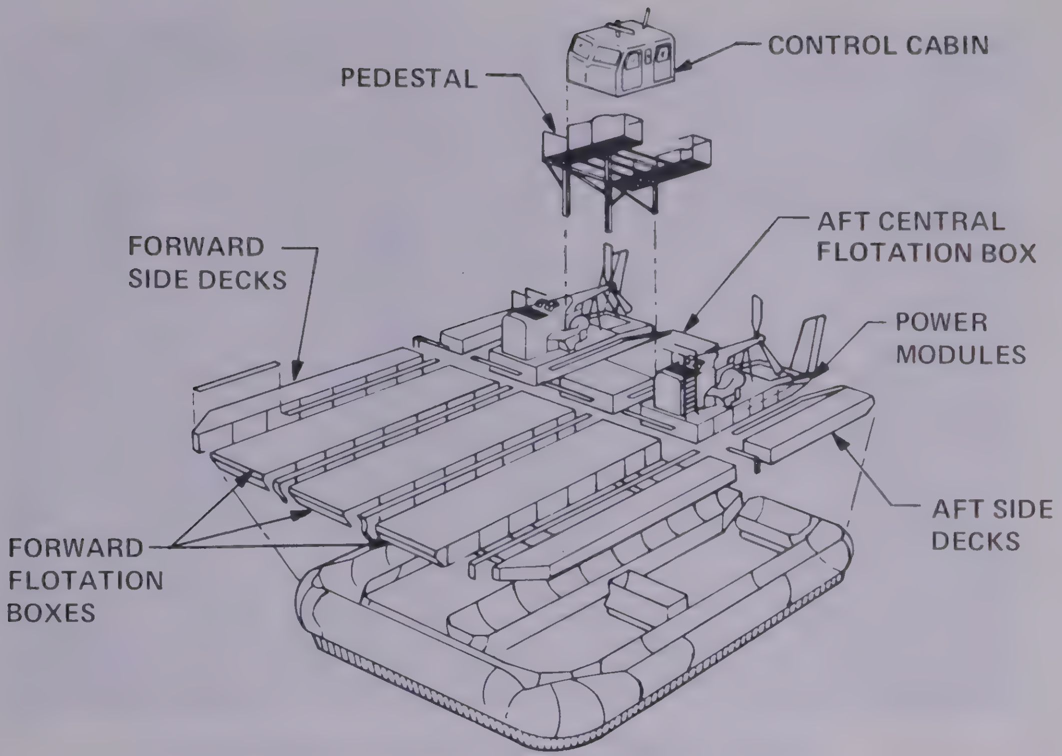

Figure 2. Exploded View of Voyageur Modules

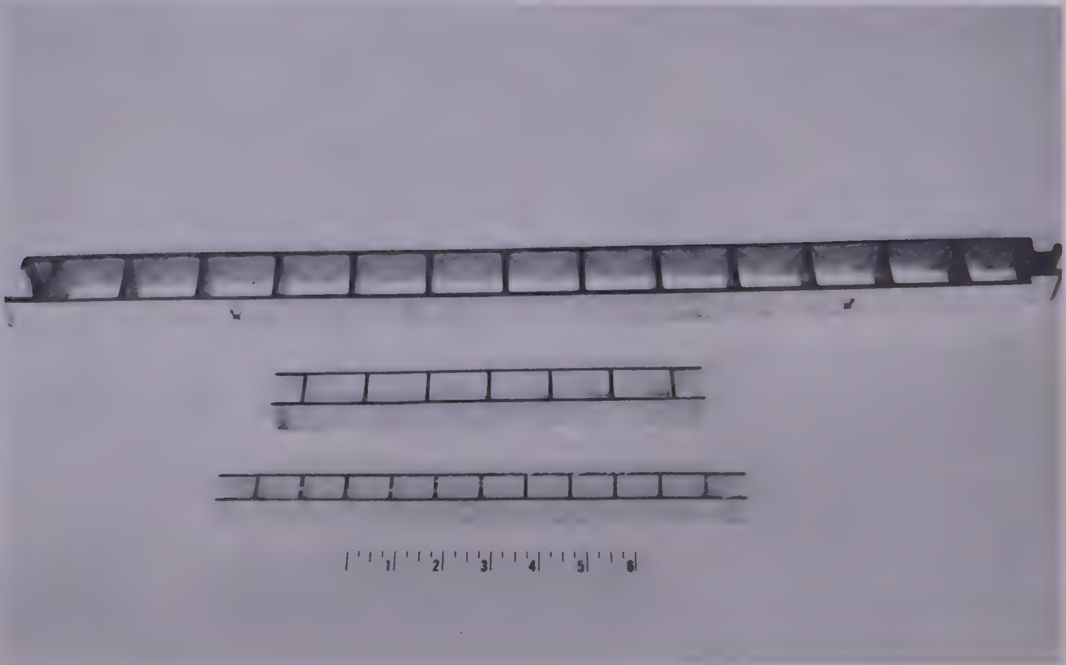

Figure 3. Extruded Hollow-Core Planks Used in Floatation Boxes

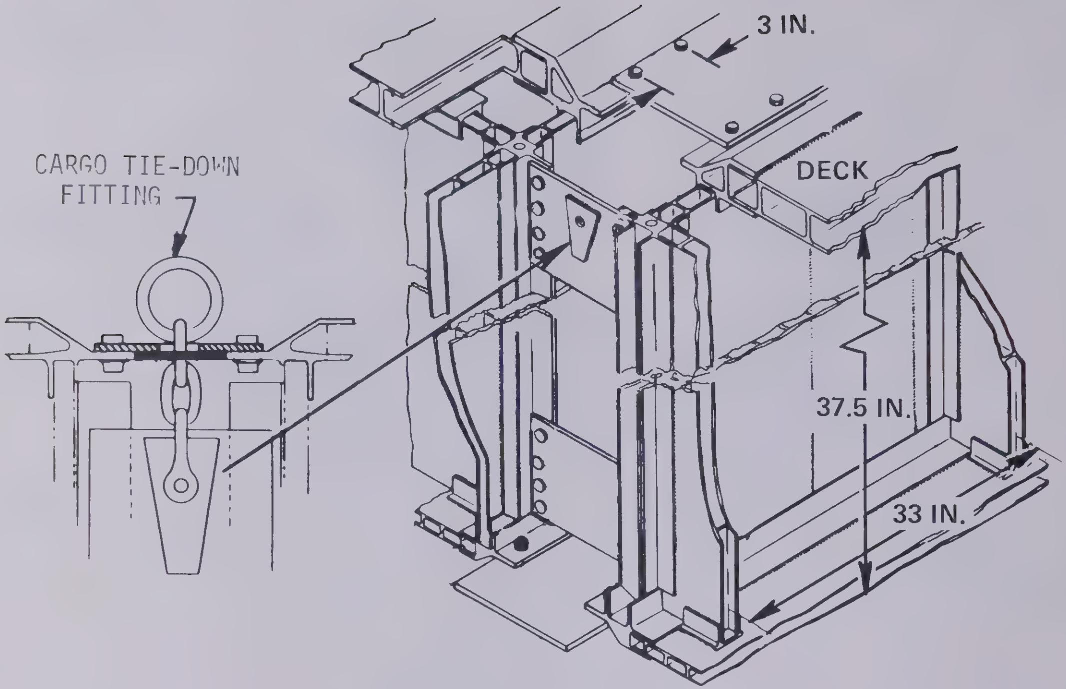

Figure 4. Forward Floatation Box Structure/Splice Assy

Figure 5. Automatic Dual-Head Hollow-Core Plank Welder

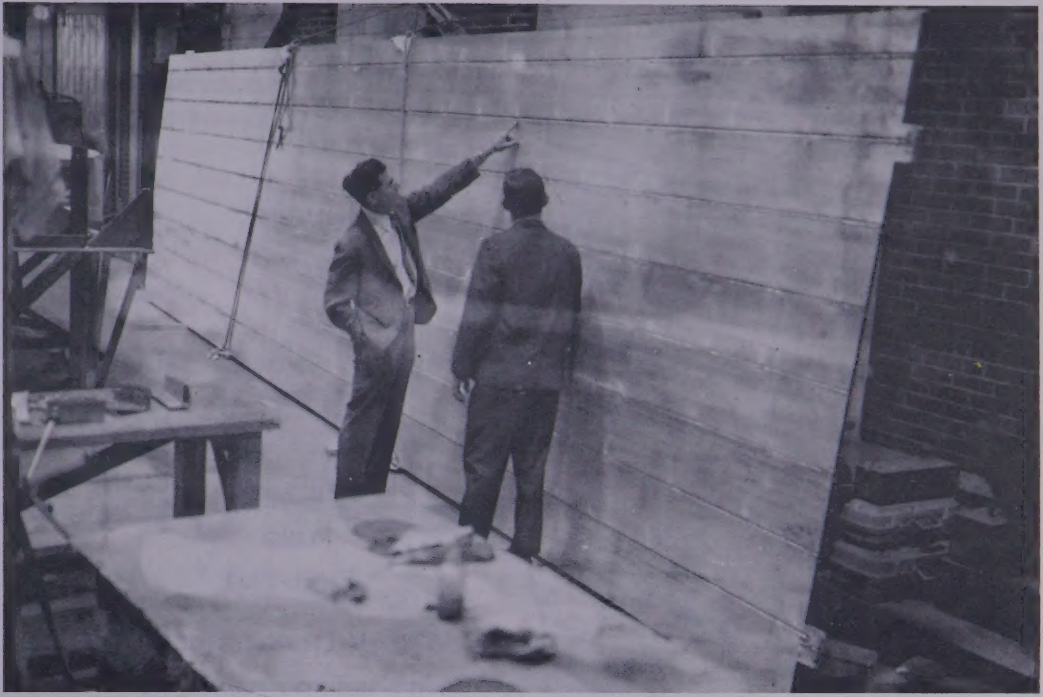

Figure 6. Welded Hollow-Core Panel - 8 ft x 32 ft

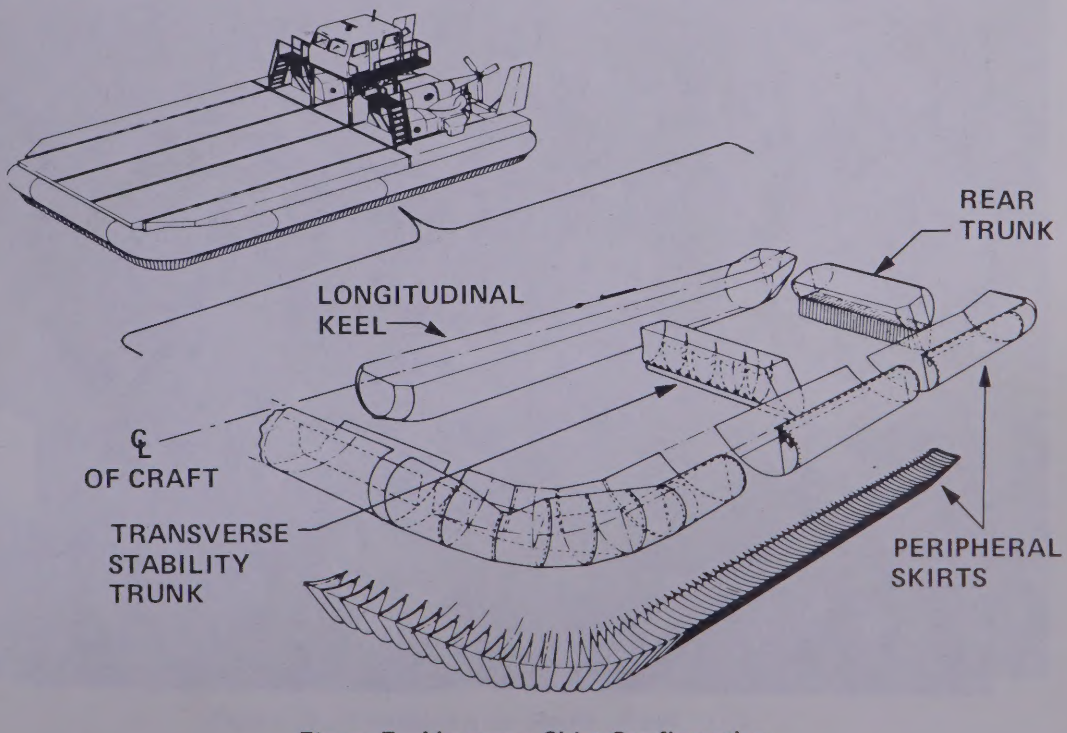

Figure 7. Voyageur Skirt Configuration

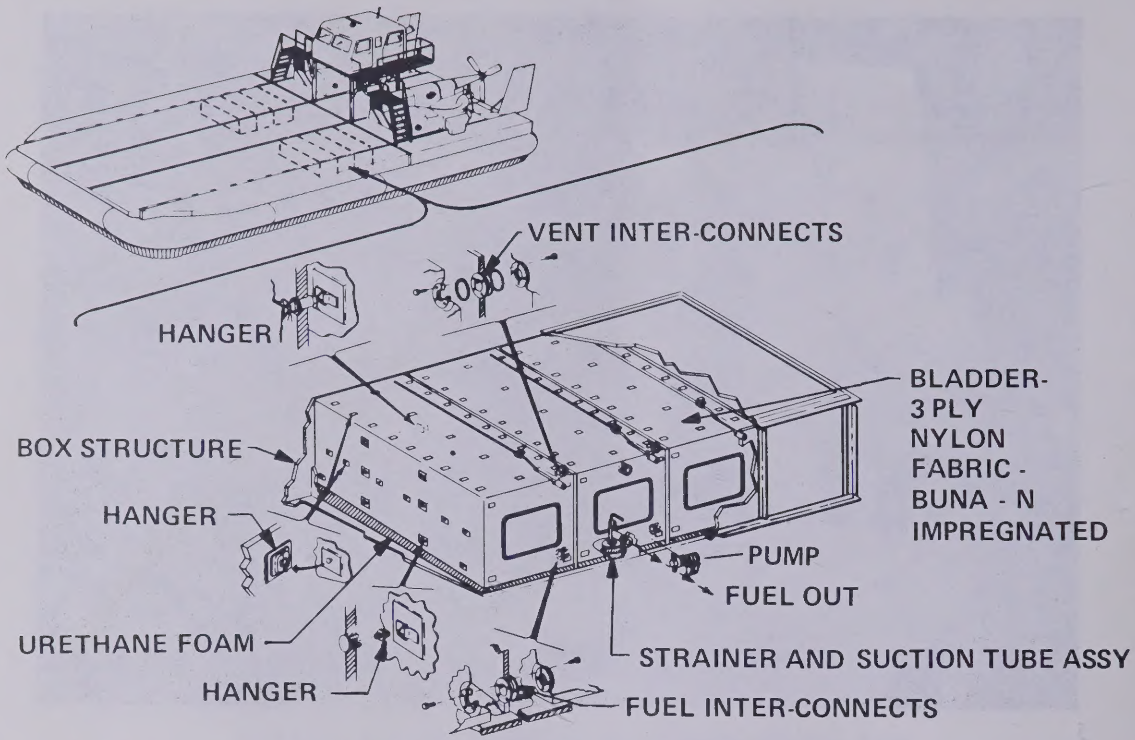

Figure 8. Port Fuel Tank Installation

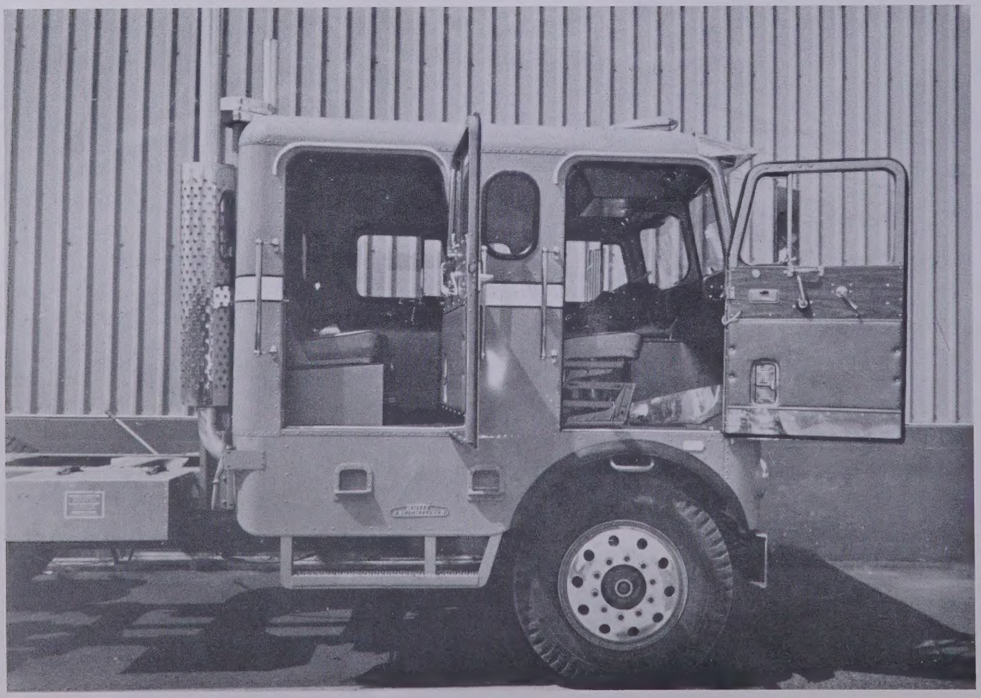

Figure 9. White Freightliner - 104 in. Truck Cab

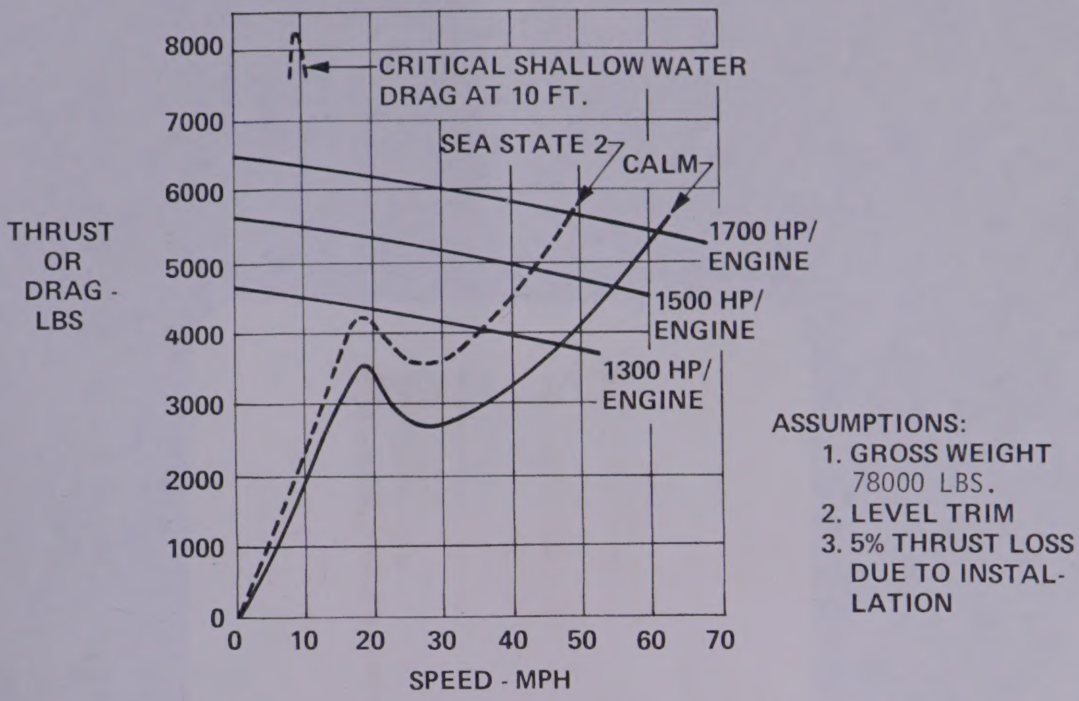

Figure 10. Estimated Voyageur Performance

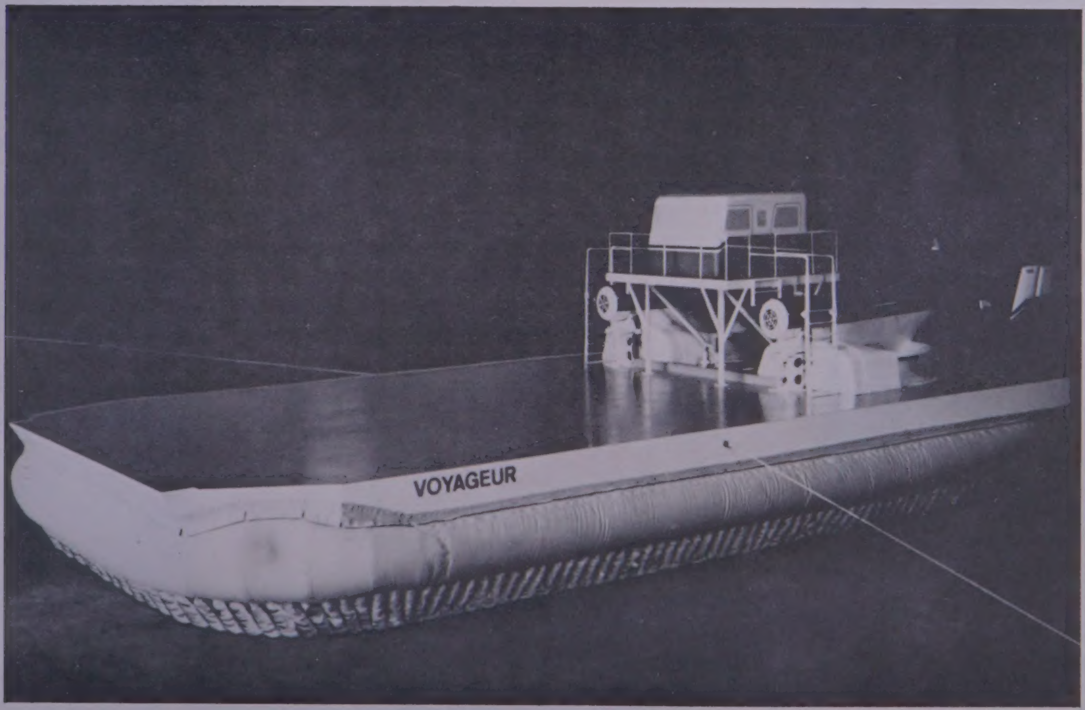

Figure 11. Voyageur Test Model - Scale 1/7.5

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